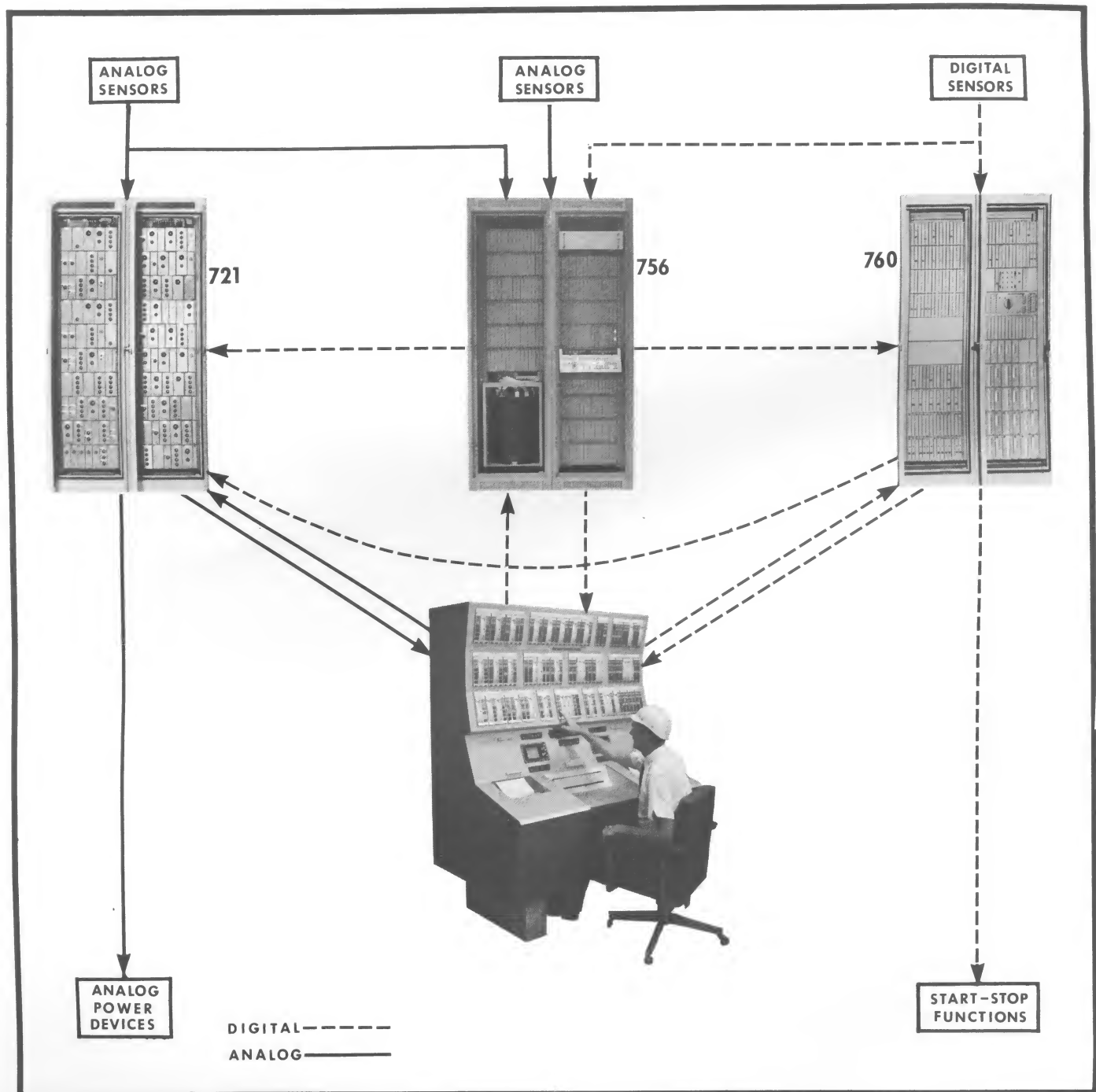


POWER PLANT AUTOMATION



Bailey 700 multi-computer control for practical automation of power plants



A highly-automated attended power plant can be accomplished with Bailey 700 Multi-Computer Control. This system provides control which improves reliability and reduces primary equipment downtime and maintenance. It combines proven concepts with proven components for practical automation of power plants.

Bailey 700 Multi-Computer Control:

- (1) Minimizes and upgrades the operator's participation to the degree that one man can properly supervise several units.
- (2) Provides an easy means for the operator to communicate with any portion of the system.
- (3) Automates many of the functions now performed manually thus reducing operator participation.
- (4) Utilizes independent parallel subloops so that many operations are performed simultaneously.

Boiler and turbine-generator subloops operate simultaneously and are coordinated with each other through the unit-management system, which provides continuous management of all functions. The concept of individually-automated subloops makes it possible to automate a power plant in steps. Where a user desires something less than complete automation the independent subloop concept makes any degree of automated control possible.

Unit-management concept

The unit-management automation concept can be likened to a company

organization. Just as the general manager interprets the policies of the chief executive officer, evaluates the status and capabilities of his divisions, coordinates their activities, and makes major decisions establishing the objectives for the divisions; so the unit-management section interprets the commands of the load control in view of the condition and capabilities of the boiler and turbine-generator, coordinates their operations, and establishes the level of demand for steam generation and power generation.

The division managers in turn must manage their respective divisions and establish requirements for subordinate departments to meet the objectives set forth by the general manager. In a similar manner the boiler and turbine-generator management sections issue the commands to the auxiliary control systems to enable them to meet the demand for steam and power.

Department heads (i.e. auxiliary equipment management) in turn report to their respective division managers and also supervise the foremen and labor force in their departments.

A general manager is never expected to assume the duties of a foreman, and the unit-management control section does not assume direct regulation of the subloops. As chief executive officer the operator functions to provide control and guidance when needed.

Three types of computers

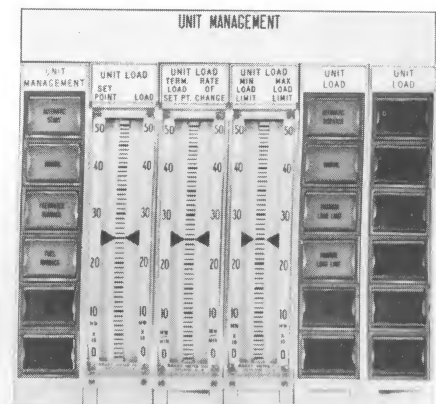
The system makes use of pro-

grammed digital, reflex digital, and analog control computers at all levels of management. Each is assigned the jobs for which it is best suited. Coordinated parallel operation of the computers simplifies programming and increases flexibility.

The normal mode of operation is completely automatic. To facilitate testing and maintenance, provision is made for operator assumption of any management function he desires.

Improves operator performance

Bailey's new operator - oriented control center provides simplified man-machine communication. The result is more accurate comprehension and the highest degree of coordination in the operator's supervision of the unit.



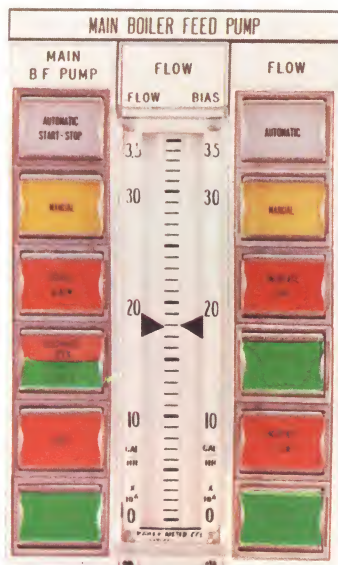
An example of simplification is the unit-management control station from which the operator has control over the complete system. When all subloops are in the automatic mode, the operator can start and stop the boiler and turbine-generator as a unit.

Centralization of control and display aids operator comprehension



Control and display functions are centralized in a single control console as illustrated on Page 4. The Bailey 700 system simplifies and upgrades the operator's duties so that one man can properly handle several units. This is accomplished not only by the automation of all subloops and management functions but also by clearly presenting pertinent status and capability information to keep the operator well informed. The console functionally centralizes the man-machine interface for the analog, reflex digital, and programmed digital computers which comprise the multi-computer system.

Pushbutton stations



Bailey 700 Multi-Computer Control System utilizes compact indicators and universal pushbutton modules that can be used for mode selection (auto-manual), start/stop, open/shut, raise/lower, increase/decrease, and annunciator functions as

required. The design of these modules permits a matrix arrangement in the organization of the management stations so that like functions are always in the same relative position.

Alarm indications are an integral part of the module and the operator's attention is drawn to the point where the fault exists and where corrective action is being automatically taken or where his participation is required.

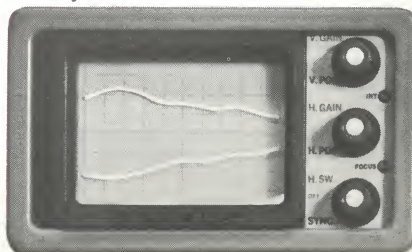
Vertical scale indicator modules provide for quick, ready determination of important control parameters.

STEAM FLOW

2 7 6 9 1



Operator interrogation of plant status is by means of simple push-buttons with word identification. No point number dictionary is required. To get a readout of any piece of information in the system he uses these buttons. For example, to obtain a reading of steam flow, he pushed "steam" and "flow". The words light up on the panel along with the current value in digital numbers and units of the demanded point. This reading is updated each data collection cycle.



Oscilloscopes provide simultaneous

display of 30-minute post-trends of four variables (2 per scope) selected from a predetermined group of 24. These trends are updated continuously with each new value. The digital displays above and below each oscilloscope display the most recent value of the measured variable selected for display.

Utilizes three printers

The alarm printer and utility printer are mounted in the console to provide up-to-date data on plant operation.

The periodic log printer (historical record) is not located in the console since information logged is historical data and is of no immediate value to the operator in the operation of the plant.

The alarm printer logs all points going into alarm and returning to normal. The operator can also demand an "off-normal" review of all points in alarm.

The utility printer logs all operator-demand printouts in formats established by the stored programs. The printouts include point demand, group demand, trend log, computed data, performance results, etc. These printouts are operator-initiated by pushbutton action.

From this one operator-oriented control center the operator has all necessary information and controls required for supervision and operation of a boiler-turbine-generator unit. The result is optimum coordination in the operator's supervision of the unit.

High availability results from application of Bailey 700 System



Power plants have become more complex. Too often the central control panels contain more information than most operators can intelligently assimilate. Some plants have as many as 2,200 indicators, recorders, lights, etc., for a single unit. It is easily understandable why an operator (or even two) finds it difficult to analyze the best action to take in a given situation with such a large amount of instrumentation that requires their attention.

The information portion of the 700 system improves operator efficiency because of the consolidation and organization of the information displayed. This results in quicker supervisory decisions. Thus unit start-ups, acceptance of load changes, and shutdown are performed in a more expeditious manner.

Better informed operators

The information portion of the 700 system can be credited with those savings that will result from keeping the operator better informed. Troubles will be detected at an early stage before damage is done. Thermal efficiency will improve with the detection of small losses otherwise unnoticed. Load changes will be made with optimum response. The unit will be on the line quicker. There will be fewer unwarranted trips. In addition, the unit will be returned to service sooner after a trip when the operator knows why it was tripped. This all adds up to higher unit availability.

The automation of many of the functions presently performed manually provide better unit availability plus increased operating efficiency through the reduction of operator

error and the ability to make control decisions previously not possible.

Minimum downtime

Operating costs are reduced by uniform, consistent, and safe operation of plant equipment, resulting in minimum downtime and maximum efficiency. Simplified diagnostic techniques for locating trouble in conjunction with modular components that are easily replaced, further reduce downtime and maintenance costs. Component standardization reduces spare parts requirements.

Equipment maintenance can be based on similar plant diagnostic techniques rather than on arbitrary time cycles. Improved management of the equipment reduces the overall maintenance required.

Savings in space and control room costs and, perhaps, some manpower reduction, reduction in installation, operating, and maintenance costs are just a few of the reasons for automating with the Bailey 700 Multi-Computer Control System.

700 systems equipment

Each management and control area consists of three related instrumentation systems:

- (1) 756 Computer System.
- (2) 721 Electronic Analog Control Computing System.
- (3) 760 Fixed-Program Digital Control Computer System.

Three basic criteria were established and met in design of this equipment. These were:

- (1) Reliability.
- (2) Flexibility.
- (3) Functional Packaging.

The 700 equipment is packaged for easy access. Since specific control subloops may be isolated as required, there is no need to completely shut down operation for servicing, calibration, or maintenance.

Standard components

Components are of solid-state modular construction. The system utilizes standard off-the-shelf modules. No one-of-a-kind modules are used. All modules and power supplies are contained in one systems cabinet assembly. Also, in this cabinet assembly are the terminal boards and test panel facilities. The modules within the systems cabinet assembly are grouped in subsystems to facilitate troubleshooting, calibration, and maintenance. There is no time sharing of electronic components between various subloops.

Factory checkout

All electronic control components are factory assembled into an engineered system for each specific application. Prior to shipment, the 700 system is given a complete test to:

- (a) Provide checkout of all inter-connecting wiring within the system.
- (b) Check the system for functional operation.

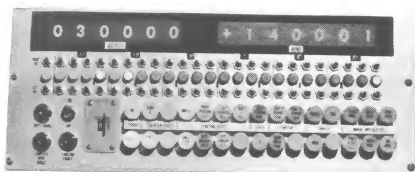
During the period of factory testing, which generally involves several weeks, power is maintained on the system day and night to assure that all components within the system are operating properly. Thus, upon shipment, the 700 system is completely checked and "run-in".

756 multi-channel computer system is designed for building block approach



Bailey 756 Computer System is designed for use in plant automation. The 756 computer system accepts analog and digital inputs, makes the arithmetic and decisional computations, and produces the required outputs—displays, records, and supervisory signals. This is done in accordance with the real-time requirements of the plant and the operator. It consists of multiple computers or subsystems each providing and fully implementing a single basic function. This system organization provides unlimited flexibility for adjustment and expansion, ease of understanding for programming and maintenance, and the highest degree of availability.

Subsystems utilize solid-state digital techniques to perform their assigned functions in accordance with their own specific programs. The program instructions for each subsystem include commands designed especially for use in implementing its assigned functions.



A program may be established and changed individually and directly for the functions involved, while other programs and subsystems continue to operate on-line. Because of the simplicity of programming, field changes can be made by the purchaser's field personnel.

The building block approach to the design of the digital system permits the construction of a multi-computer system to meet the requirements of any unit. The Bailey 756 system for the highly automated power plant is comprised of as many subsystems as

necessary to meet these requirements.

1. Data acquisition computer

Fresh information is continuously provided to data storage by the data acquisition computer. The only function of the data acquisition computer is to continuously update the information in data storage. It scans all system inputs at frequencies required by plant dynamics and by the importance and use of the inputs.

2. Data storage

The single function which contributes most to the effectiveness of the Bailey 756 Computing System is the data storage section. It consists of an area of system memory in which all system data is stored and made simultaneously available to all monitoring, manipulating, and display functions. Any display, output, mathematical operation, or other system function has access to the data independently of and simultaneously with any other system.

3. Alarm monitor computer

Fresh information and computed results are continuously checked against stored set points. Any alarm change initiates annunciator actuation and printouts on the alarm printer when a point enters alarm or returns to normal.

4. Mathematical operations computer

The mathematical operations computer is a binary-coded decimal arithmetic, digital computer designed as a part of the 756 system and devoted only to calculations and computations. During normal on-line operations, the computer continuously and automatically performs accumulations and averaging calculations plus

desired performance calculations.

5. Operations monitoring computer

This computer automatically and continuously monitors and supervises startup, normal operation, and shutdown procedures. Demand signals from the operator are not required. It operates to automatically determine what period of operation exists and then performs the necessary sequence and safety monitoring routines for that period. It warns the operator of impending unsafe conditions to permit corrective action before an expensive trip becomes necessary. It also indicates what the corrective action should be.

6. Output computer

The output computer can drive both the periodic and utility log printers. The output computer executes stored programs as demanded by the operator or as called for automatically.

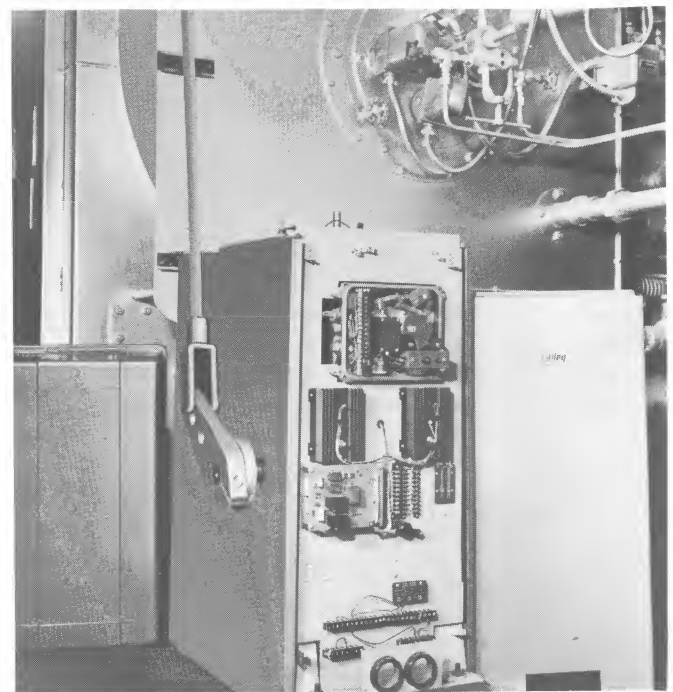
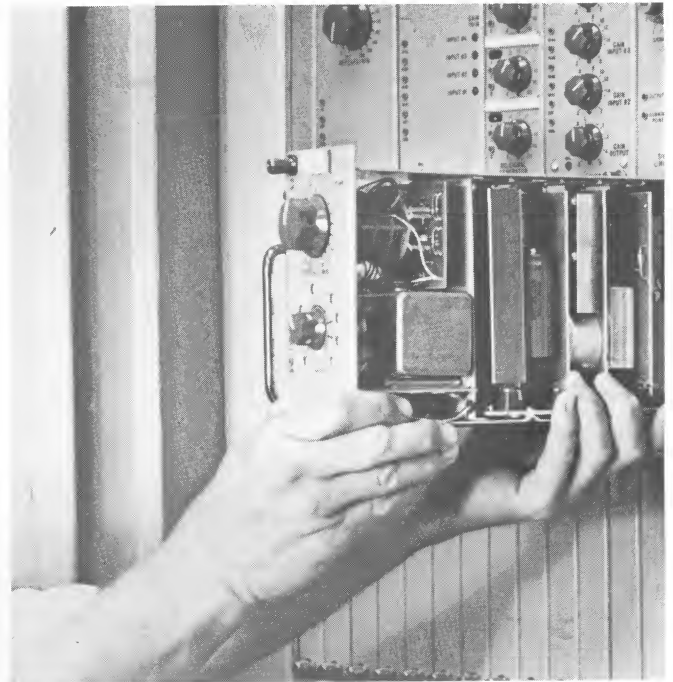
7. Display computer

The display computer continuously scans all information in system data storage and distributes selected items to digital indicators and analog recorders.

Step-by-step approach

A significant advantage of the 756 system is that automation can be achieved through a step-by-step approach with each step added as it becomes justified. If all that can be justified initially is data logging and alarm monitoring, the 756 system can be designed to accept additional computers with minimum disturbance to plant operations, as the additional functions become defined and justified.

721 electronic analog computer control assures consistent, accurate performance



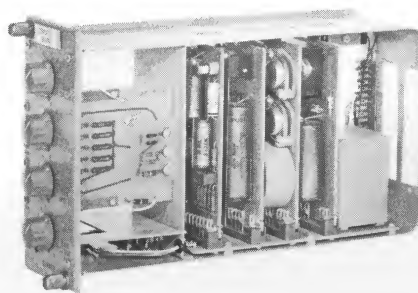
The 721 portion of the Bailey 700 Multi-Computer Control System is an analog computing control system which is individually tailored by Bailey engineers to meet specific requirements. Extensive experience in application knowledge coupled with modern techniques assure consistent and accurate performance.

The 721 analog electronic computer control system is designed to meet and handle the complex control problems of today's modern power plants. Simple single-loop control can no longer cope with the demands required of it by the power plant. The modern power plant is a complex process with many interacting and interdependent functions. The 721 system is designed to handle the control problems posed by such complex processes. The requirements for multi-loop feed-forward type of control, with adaptive and optimizing features have been recognized in component and system design. The 721 system provides fast control of the system functions. Today's power plants, due to increased capital expenditures, have reduced storage thus increasing the process dynamics.



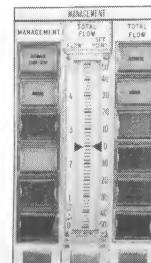
Transmitter output (± 10 volts dc)

is directly proportional to the measured variable.

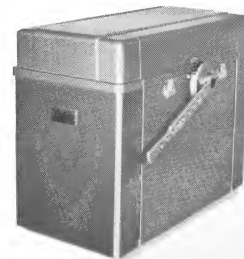


All control action units are built around the same basic analog computer-type operational amplifier. These are plug-in components and are mounted in the electrical system cabinet assembly. The action unit receives electronic control signals from transmitters, controllers, and/or other action units and produces a control signal according to the action desired. The control actions available are: proportional, summing, integral, derivative, proportional plus integral, proportional plus derivative, and signal lag.

A complete line of supplementary units are available to provide a complete line of equipment necessary to properly automate the modern complex power plant. They include fixed signal units, adjustable signal units, auctioneering units, limiters, etc. Computing units such as multipliers, square root extractors, and function generators are available to provide necessary computing functions. These items are not one-of-a-kind, but are standard off-the-shelf units. These units are of solid-state electronic circuitry with transistorized components.

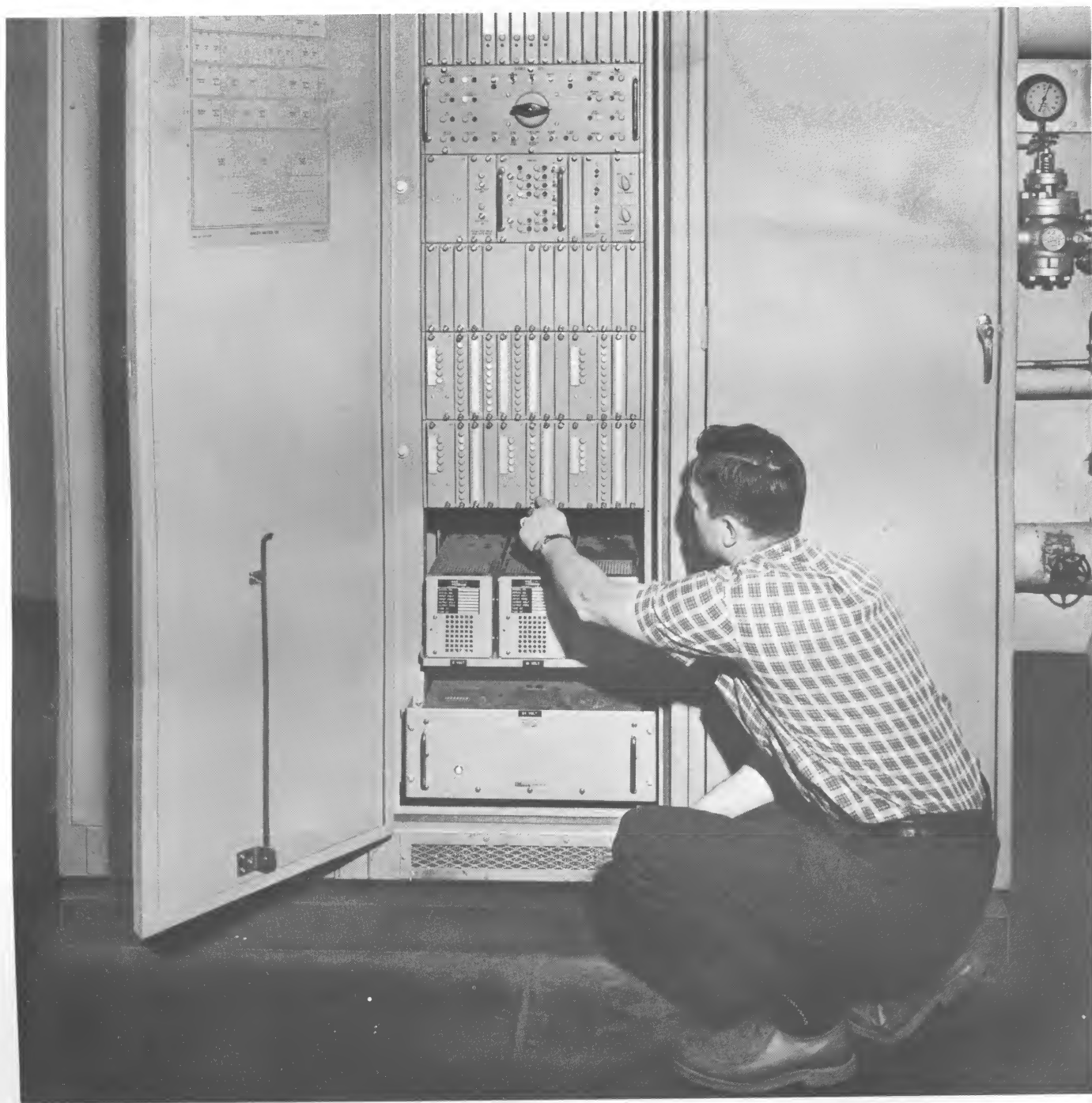


The pushbutton selector station can be switched from automatic to manual operation or from manual to automatic operation without intermediate balancing or adjustments. An automatic transfer from automatic control to manual control always takes place upon power failure thus holding the final control element in position.



The electric control drive provides modulating remote-control power for precise positioning of regulating devices. It receives an electric signal from the control system or from a remote manual operator, compares it with a characterized position feedback signal representing drive position, amplifies the resultant error signal, and operates the drive motor in such a direction and at a speed so that the required position is obtained with optimum stability. Rated torques available from 100 to 3200 lb-ft with stall torques of 300% of rated torques.

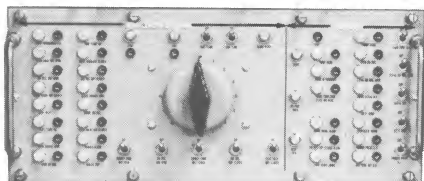
760 fixed-program digital computer provides safe, reliable supervision



Each management subloop control system has certain sequential start-stop functions that must be performed. The 760 fixed-program digital computer (reflex digital control) is used to control these functions. As it proceeds through the sequence, each step is checked to see that the operation is actually performed. The system uses only closed-loop timed based sequences. Should a piece of equipment malfunction, the 760 digital system will automatically go into shutdown or hold sequence to prevent an unsafe condition or harmful operation of the equipment.

System nerve center

The 760 digital system is the nerve center of the system. This is where the logic decisions are made and the start-stop sequences are coordinated for smooth operation of all subloops. It is used throughout the multi-computer control system for control of plant auxiliary equipment, opening and closing of valves, burner control, plant safety systems, etc.



The custom-designed sequence test panels provide a tool for the service engineer or maintenance man to quickly check out the logic system functions and to pin-point any logic malfunction to a particular area in the system.

Used for burner control

One of the many places that the Bailey 760 Fixed-Program Digital Computer is used is for burner control. It is designed with necessary solid-state logic circuitry for the following sequences:

- (1) Furnace purge sequence.
- (2) Boiler interlock safety sequences.
- (3) Individual burner flame monitoring.
- (4) Burner light-off sequence.
- (5) Burner trip sequence.
- (6) Ignitor light-off and trip sequence.
- (7) Automatic load sequencing (from the appropriate demand signal).

Once a burner is started, certain operating parameters are monitored continuously such as main flame, air register position, fuel valve position, etc. Should any of these fail or malfunction, the system will automatically shutdown that burner on which the failure occurred. The system automatically trips the furnace in an orderly sequence if a monitored fault indicates a continued operation of the boiler would cause a hazardous condition.

The load sequence automatically initiates and secures burners on demand from properly developed firing rate indices. This removes the requirement for operator participation and keeps an optimum number of burners in service to meet unit load.

The integrated system

Each management and control area

consists of 3 coordinated instrumentation systems:

- a. Start-stop sequential digital control equipment.
- b. Analog control equipment.
- c. Sub-loop supervisory digital instrumentation.

The three types of computers, 756 program digital, 721 analog control, and 760 reflex digital computers are integrated into one system to provide the management and control functions required.

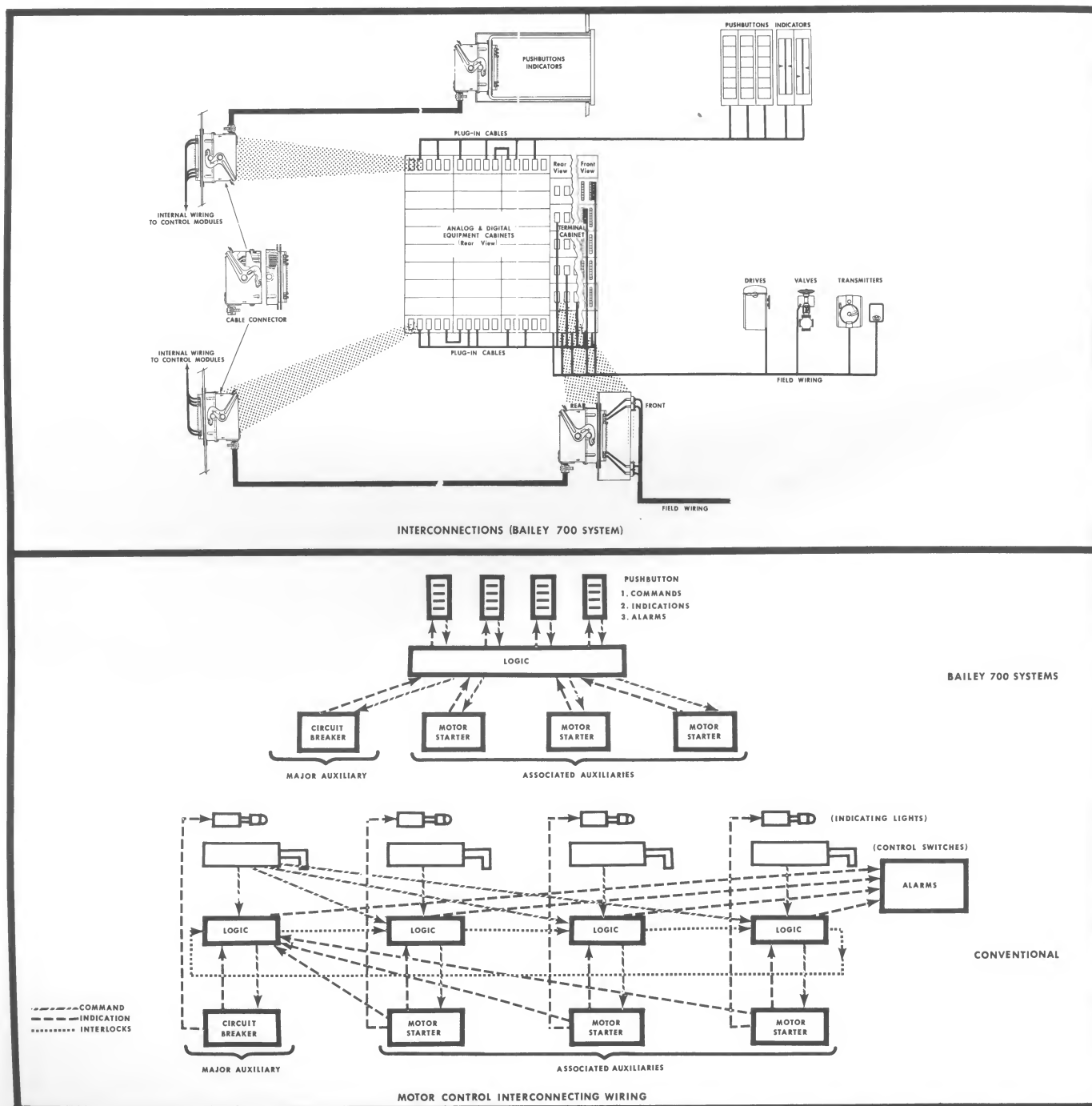
This organization of the plant management and control system provides the proper operating relationships between the areas to provide a complete highly automated attended power plant.

5 major benefits

This concept of control:

- (1) Provides a more understandable instrumentation system for operators and maintenance personnel.
- (2) Improves reliability by reducing dependency on common time-shared facilities and, thereby, the effect of individual equipment failures.
- (3) Simplifies maintenance by providing a natural and logical instrumentation grouping for isolation and repair.
- (4) Minimizes the need for "programming" in the accepted sense. Only straight-forward sequence steps are required.
- (5) Permits compact control centers with improved operator orientation.

700 multi-computer system reduces installation costs



Bailey 700 Systems are designed as a series of building blocks of modular design for plug-in mounting in system cabinets of standardized design.

Standardized cabinets

Each system cabinet is 84" high, 24" wide, and 24" deep. System cabinets are constructed from $\frac{1}{8}$ " steel plate, which is reinforced so as to be a rigid self-supporting cabinet for equipment mounting. Filters and plenum chambers are provided at the top and bottom of each cabinet to allow air distribution for cooling purposes.

A system can be made up of as many standard system cabinets as necessary; the cabinets being bolted together to form a single rigid assembly.

Each plug-in module contains a blue-ribbon connector to mate with another blue-ribbon connector mounted on the mounting rack within the system cabinet. System reliability is increased due to gold-plated contacts in the blue-ribbon plug and socket. This assures faultless transmission of voltage signals into and out of the modules. The blue-ribbon connector design provides the self-aligning of plug and socket, making the plugging in or removing of modules easy to accomplish without the use of special tools, and further, without any possibility of damage to connectors or modules.

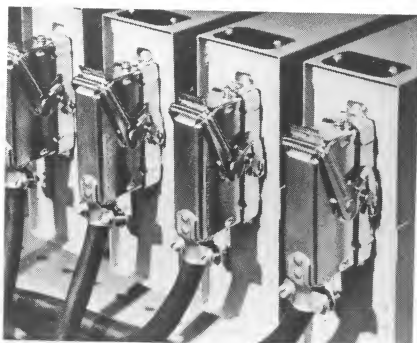
Interconnections reduce costs

Advantages of the Bailey 700 system interconnections include:

- (1) Reduced field wiring costs.
- (2) Improved over all job schedule.
- (3) Factory tested cabling.
- (4) Reduced maintenance costs with standardized replaceable plug-in cables and modular interchangeable control components.
- (5) Reduced spare parts requirements.

The terminal cabinet and the analog and digital equipment cabinets are manufactured as separate sub-assemblies. The terminal cabinets are shipped early in the project schedule, allowing the field wiring to proceed to completion as early as necessary. All field terminations are made to terminal blocks located on the front side of the terminal cabinets.

The analog and digital equipment cabinets arrive on the job site as they are required later in the project schedule. All interconnections are made in a matter of days instead of weeks. The terminal cabinets and the equipment cabinets are interconnected with prefabricated plug-in cables.



Similarly, using modular pushbuttons and indicators on the control

console, all interconnections between the control console and the equipment cabinets are made with prefabricated plug-in cables.

Motor control interconnecting wiring

Advantages of Bailey's motor control interconnections include:

- (1) Reduced field wiring costs.
- (2) Factory wired and tested interlock circuitry.
- (3) Standardized design.
- (4) Reduced maintenance with interchangeable modular components.
- (5) All components subject to controlled atmosphere only.
- (6) Reduced spare parts requirements.

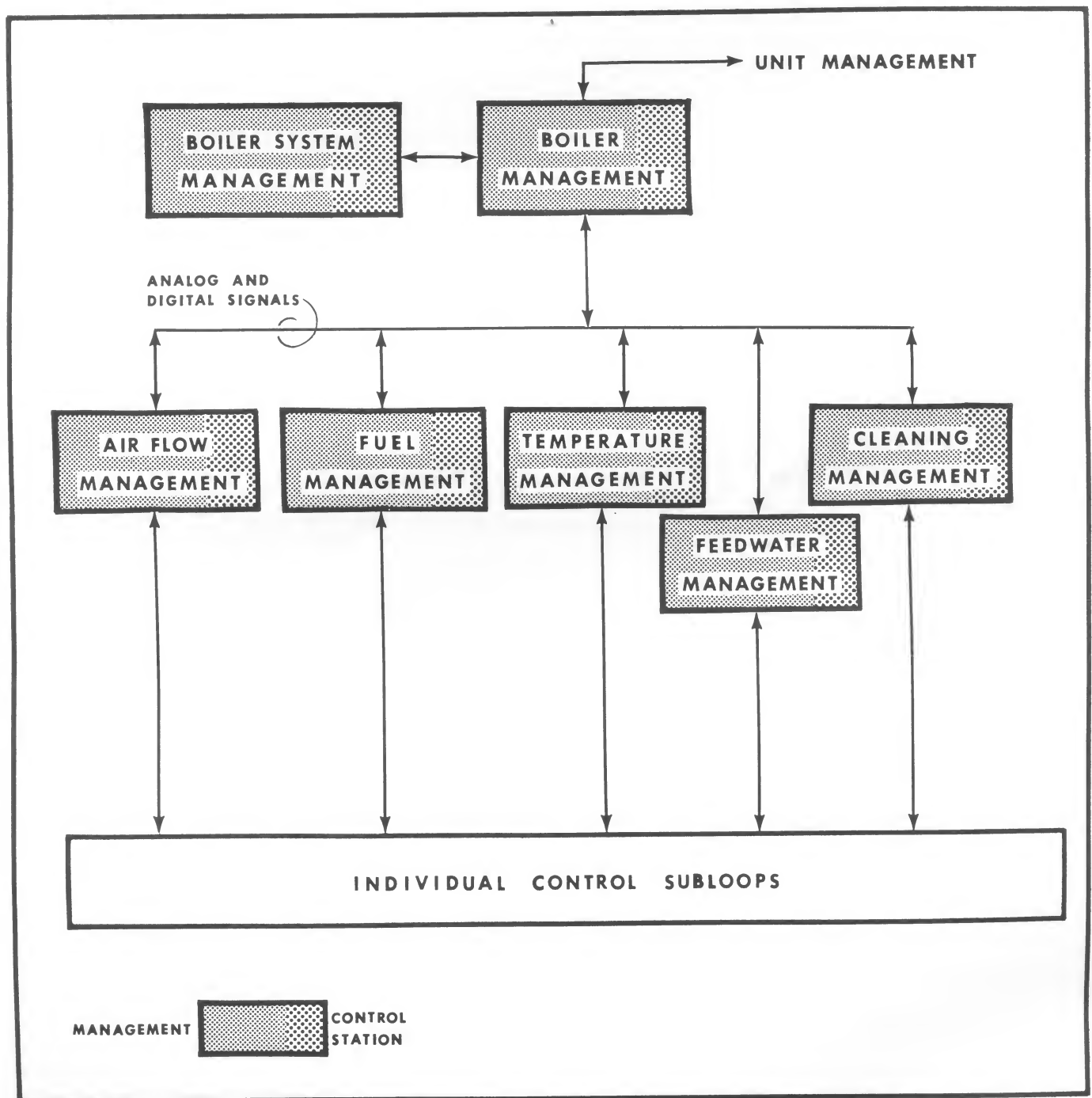
Shown on page 14 (bottom) are two approaches to the arrangement of motor control circuitry.

The conventional approach uses rotary switches and separate indicating lights. Furthermore, it usually locates the auxiliary relays necessary for interlocking and timing in switch-gear cubicles, motor control centers, and other separate cabinets.

As a result, the interconnecting cables usually take a pattern somewhat like that shown for the conventional approach.

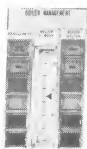
Bailey locates all of the relays or logic in a pre-engineered modular assembly. Interconnections consist of a single cable to each circuit breaker or motor starter, with only three command wires and three indicating feedback wires in each cable. All interconnections for sequencing and interlocking are contained within the logic assemblies.

Boiler management is directly responsible for control of the boiler and its auxiliaries

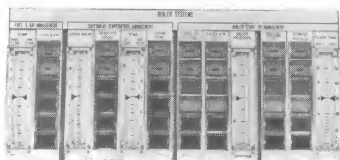


Boiler management establishes "demand" for its subsystems services based on the requirements set forth by unit management. The status and capabilities of each of the boiler sub-loops is continually considered. Operation of all auxiliary equipment is coordinated to efficiently and promptly meet the required demand for steam.

The boiler control stations are on a 1-to-1 basis with the functional arrangement as shown on page 16.

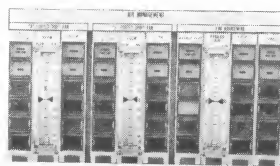


The boiler management control station provides an analog indication of the boiler demand as determined by unit management. If the need arises, operator participation permits starting or stopping the boiler and increasing or decreasing the boiler demand from this station.

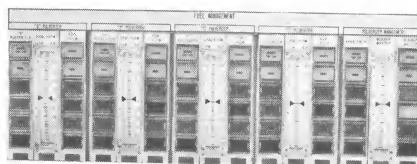


Of primary concern during start-up, the boiler systems station acts as a staff function feeding information to and receiving commands from boiler management. It provides indications of fuel flow-air flow ratio, spray valve position, steam temperature, boiler pressure, and flash tank pressure and level. Alarm indications

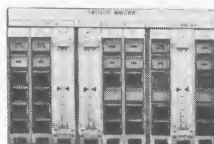
for fuel and air limits, and low and high superheat temperatures are included as an integral part of this station. Station as shown is for a once-through boiler application.



Air management station includes pertinent information on forced draft fan operation and fan management. Operator has the ability to start and stop fans, increase or decrease bias and flow, and open or close discharge of individual forced draft fans. Indications of oxygen, excess air, and purge status keep operator informed of air requirements.

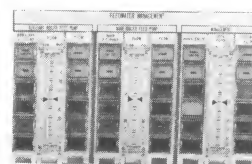


Option of individual pulverizer control as well as status and alarm information is provided by fuel management station. Pulverizer management section includes a burner master and purge control.



Temperature management station provides indications of reheat temperature, fan loads, and damper

positions. Trouble alarms and means for remote manual control of reheat temperature, gas recirculation fans, and tempering and recirculation dampers are also included.



Indications of total feedwater flow, and of main and auxiliary feed pump flows, in conjunction with trouble alarms, in the feedwater management station keep the operator well informed of the status of this vital parameter. If necessary, the operator can manually control either main or auxiliary feed pump.

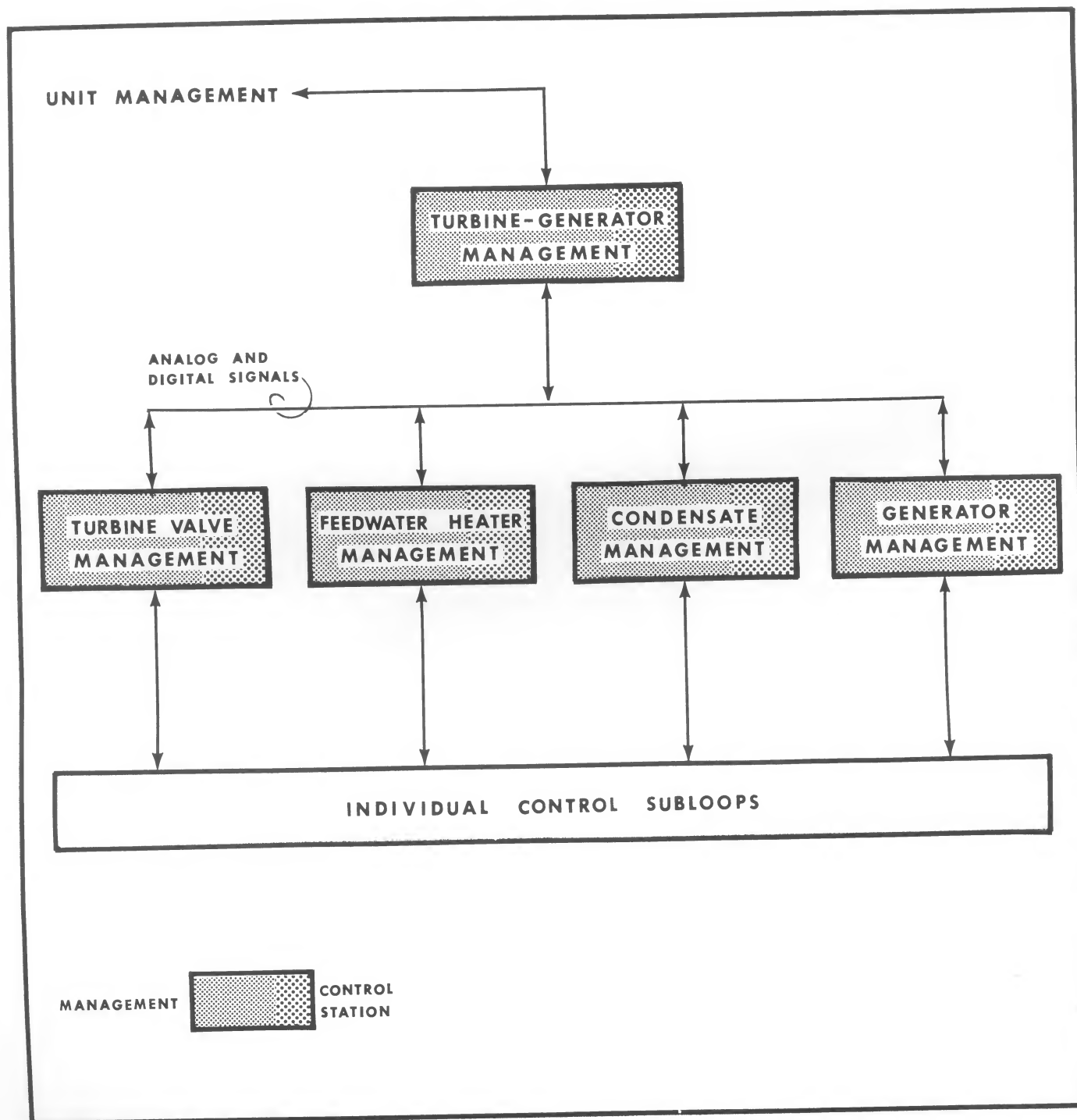


Cleaning management station provides indications of soot blower operation and permits the operator to increase or decrease the soot blower pressure set point.

Coordinated operation

Boiler management operates in parallel with the turbine-generator management. However, the status and capabilities of the boiler auxiliaries are coordinated with the status and capabilities of the turbine-generator auxiliaries through the unit-management system which provides continuous control of all functions.

Turbine-generator management centralizes control and supervision

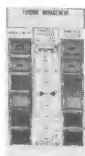


Turbine-generator management interprets the commands of the unit management system, establishes a demand signal for the turbine-generator auxiliaries, and checks the action of its subsystems to assure that the power generated meets the needs as determined by the load control.

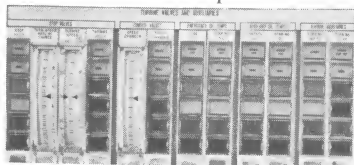
Information as to the status and capabilities of the various subloops is continuously compared to the desired demand. The system automatically adjusts the controls to maintain optimum generation.

Action of turbine-generator management is coordinated with boiler management through the unit-management system. This assures that the control system meets the demand for both power and steam generation.

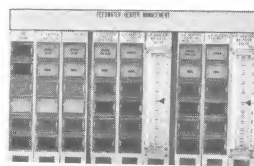
As was the case with boiler management, the turbine-generator control stations are on a 1-to-1 basis with the functional arrangement as shown on page 18.



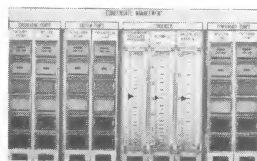
Turbine management station provides an analog indication of throttle pressure and set point. From this station the operator can start and stop the turbine as well as increase or decrease the throttle pressure.



Indications of turbine speed change and rate of change, speed changer position, and status of control valves and turning gear are provided by the turbine valves and auxiliaries station. If necessary, the operator can control the rate of change and speed set point as well as opening or closing the stop valve. Emergency and auxiliary oil pump startup and shutdown, opening and closing turbine drains, and starting and stopping of turning gear, while normally automatically controlled, can be remote manually controlled from this station.

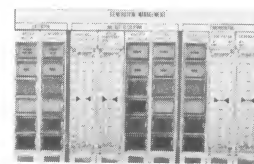


Feedwater heater management station keeps operator informed of the status of the heater drain pumps and valves, heater feedwater valves, and by-pass valves. Level alarms for heater drain pump high and low pressures alert operator of pending troubles. The same back-lighted pushbuttons which indicate status are used for remote manual control of the various pumps and valves.



Condenser absolute pressure, hotwell level, and water storage level are indicated by the condensate manage-

ment station. Operator may, if necessary, assume control of circulating, vacuum, and/or condensate pumps from the automatic control system.



Generation management station consists of three basic sections: excitation, voltage regulation, and synchronization. Operator is provided with indications of voltage regulator output, field rheostat voltage, individual phase currents, and vars. Exciter motor, generator field, voltage regulator, field rheostat, and generator breaker may be manually controlled from console.

Complete power plant automation

Bailey Meter Company is ready to provide control systems for fully automated, attended, "push-button" power plants using proven concepts and proven components.

The 700 multi-computer control system is composed of all solid-state electronic equipment and uses three types of computers:

- (1) Analog.
- (2) Reflex digital control.
- (3) Programmed digital logic.

The concept of individually-automated subloops makes it possible to automate the power plant in steps. Bailey Meter Company can provide power plant automation to any degree.

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